Methods for Fabricating Arrays of Holes Using Optical Interference Lithography

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Optical interferometric lithography has been successfully applied for well over a decade to pattern 1D and 2D arrays of structures for a wide variety of uses. Recently, interest in this relatively inexpensive technique has grown as new, commercially viable applications have emerged including the fabrication of field emission flat panel displays [1,2]. The advantages of using interferometric techniques over other lithographies are that deep submicron resolution can be achieved over large field sizes (50 ¥ 50 cm^2) with an effectively infinite depth-of-focus.

Recent studies have shown that arrays of high aspect ratio posts (3:1) can readily be produced using 2-beam interference patterns and positive i-line resists [3]. However, the fabrication of arrays of holes—which is particularly important for many applications—is limited by the characteristic sinusoidal shape of the 2-beam pattern. This handicap can be overcome by several different methods. One approach is to modify the shape of the intensity distribution by combining more than two coherent beams. For example, intersecting three, four, or five coherent beams, can produce a much sharper intensity profile. A recent study suggests that the 4-beam arrangement—whereby four beams converge at equal angles from orthogonal directions—is particularly effective for patterning hole arrays in resist [4]. An alternate approach is to combine 2-beam interference lithography with image reversal.

In this study, these two methods for patterning arrays of submicron size holes are compared. We show that while the 4-beam technique can yield a sharper aerial image compared to a 2-beam interference pattern, it is complicated by an inherent sensitivity to the relative phases of the beams. A detailed analysis reveals that under certain phase conditions the intensity modulation of a 4-beam interference pattern is actually weaker than it is for a 2-beam pattern. The implications of these results for practical applications of the 4-beam approach are discussed. Finally, we show experimental results of applying image reversal techniques to standard 2-beam interference lithography and demonstrate that arrays of submicron diameter holes can be produced by this method. These holes are characterized by steep sidewalls and are well suited for subsequent pattern transfer.

[1] C. O. Bozler, C. T. Harris, S. Rabe, D. D. Rathman, M. A. Hollis, and H. I. Smith, *J. Vac. Sci. and Technol. B* **12**, 629 (1994).
[2] J. P. Spallas, R. D. Boyd, J. A. Britten, A. Fernandez, A. M. Hawryluk, M. D. Perry, and D. R. Kania, *J. Vac. Sci. and Technol. B* **14**, 2005 (1996).
[3] A. Fernandez, H. T. Nguyen, J. A. Britten, R. D. Boyd, D. R. Kania, A. M. Hawryluk, and M. D. Perry, submitted to *J. Vac. Sci. and Technol. B.*
[4] X. Chen, S. H. Zaidi, S. R. Brueck, and D. J. Devine, *J. Vac. Sci. and Technol. B* **14**, 3339 (1996).

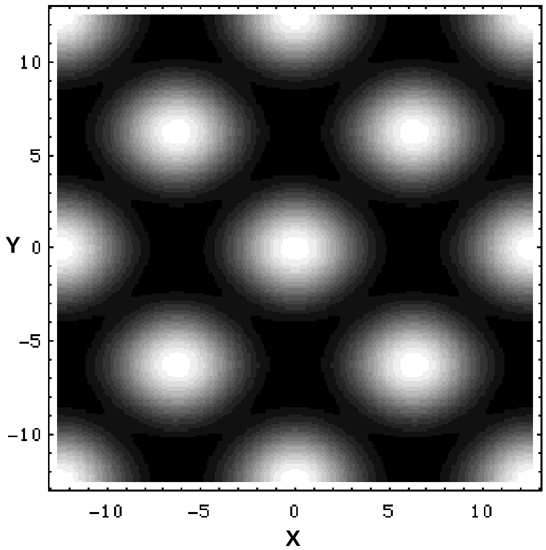

Fig. 1. The 2D intensity pattern formed by intersecting 4 coherent plane waves incident at an angle of 30∞from the normal. Two beams are incident from the ±x directions and two are incident from the ±y directions.

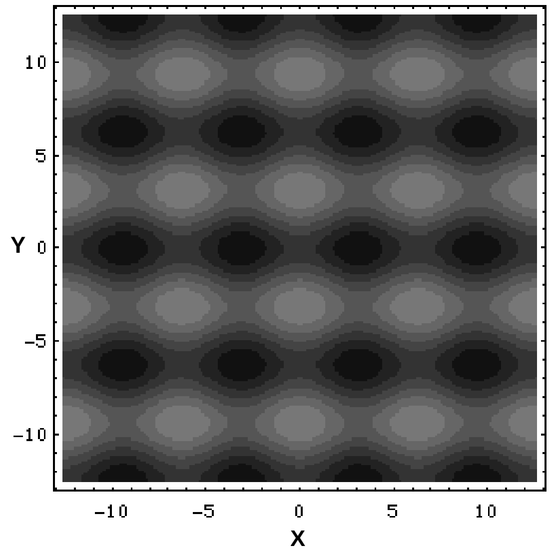

Fig. 2. The 4-beam interference pattern of Fig. 1 after a phase shift of 180∞ has been added to the beam incident from the +y direction. The loss in modulation is problematic for printing arrays of holes using this approach.

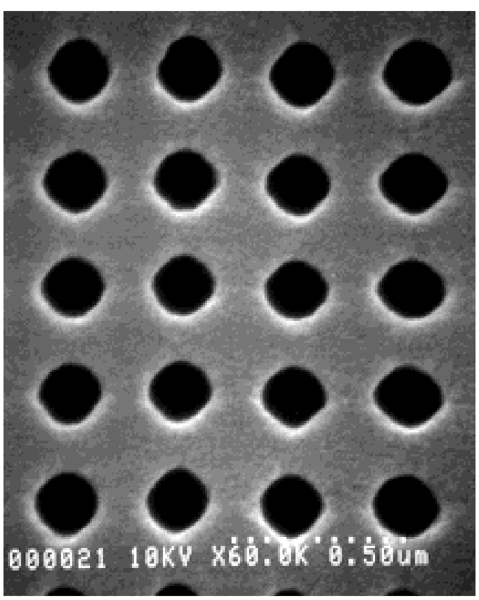

Fig. 3. SEM of an array of 0.16 mm size holes in 0.45 mm of resist patterned by overlaying two sequential 2-beam exposures at 90∞ followed by image reversal. The grid spacing is 0.3 mm.

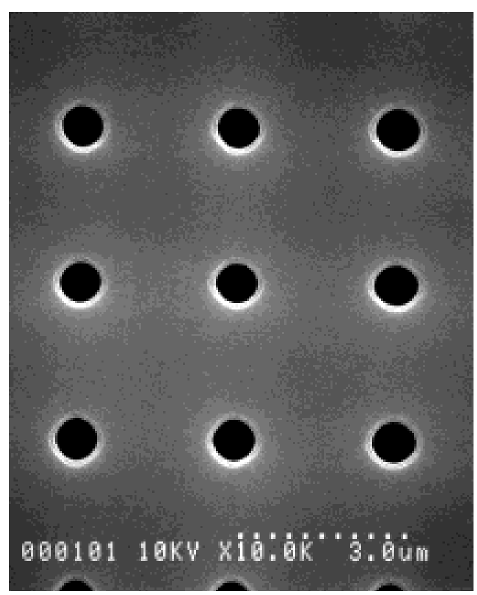

Fig. 4. SEM of an array of 0.67 mm size holes in 0.9 mm of resist patterned by overlaying two sequential 2-beam exposures at 90∞ followed by image reversal. The grid spacing is 3.0 mm.